Back on Track
Bundle Adjustment for Dynamic Scene Reconstruction

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ICCV OCT 19-23, 2025 HONOLULU HAWAII

Task: Dynamic Scene Reconstruction

Goal: Recover camera poses and 3D geometry for dynamic scenes

Our approach: BA-Track

- We learn to undo the motion of the dynamic objects, thus allowing standard SfM/SLAM to handle static and dynamic points alike

Pipeline: motion decoupling → bundle adjustment → global refinement

Motivation

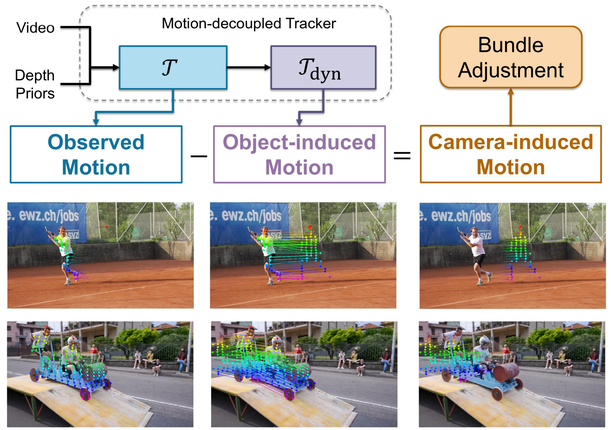
Casual videos contain both camera movement and object dynamics

Camera Movement
↓
Epipolar geometry holds
→ Bundle adjustment works 👍

Object Dynamics
↓
Epipolar geometry breaks
→ Bundle adjustment fails 😳

Challenge: Can we integrate dynamic points into bundle adjustment?

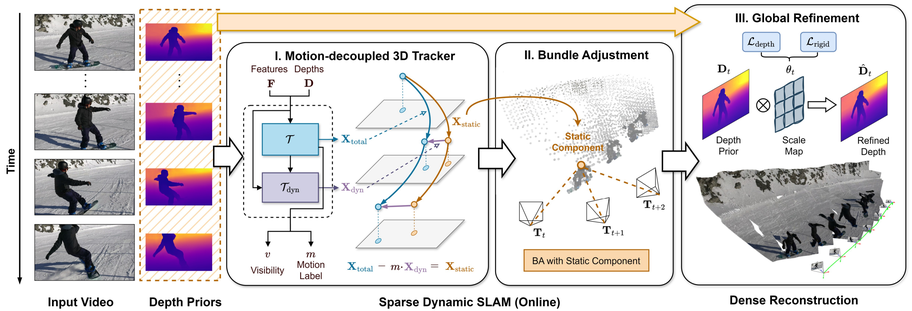
Motion Decoupling



Motion-decoupled Tracker

- Leverage temporal context
- Capture 3D motion patterns
- Dual-network design

BA-Track Framework



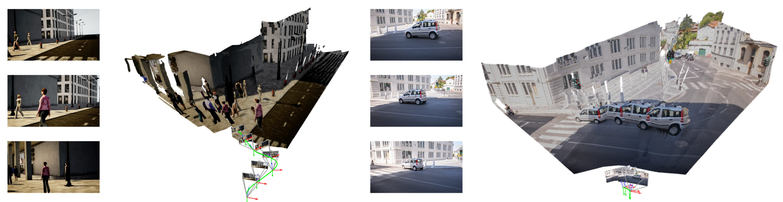
I. Estimate local-window 3D tracks and decouple the camera-induced component
II. With the camera-induced component, BA can be applied to both static and dynamic points
III. Align depth priors with sparse BA estimates to achieve a consistent, dense reconstruction

Results

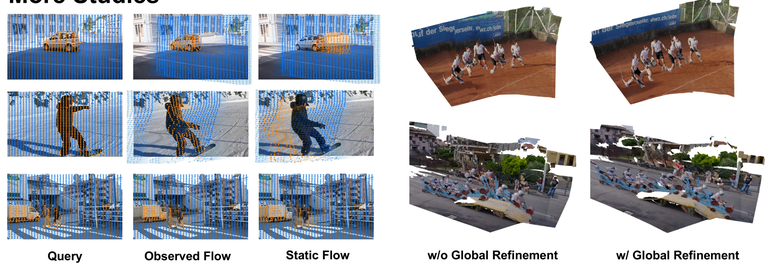
Camera Tracking

Category	Method	MPI Sintel [6]			AirDOS Shibuya [30]			Epic Fields [40]		
		ATE	RTE	RRE	ATE	RTE	RRE	ATE	RTE	RRE
w/ intrinsics	DROID-SLAM [37]	0.175	0.084	1.912	0.256	0.123	0.628	1.424	0.130	2.180
	TartanVO [43]	0.238	0.093	1.305	0.135	0.030	0.249	1.490	0.121	1.548
	DytanVO [34]	0.131	0.097	1.538	0.088	0.026	0.251	1.608	0.119	1.556
	DPVO [38]	0.115	0.072	1.975	0.146	0.091	0.387	0.394	0.078	**0.734**
	LEAP-VO [7]	0.089	0.066	1.250	0.031	0.111	**0.124**	0.486	0.071	1.018
w/o intrinsics	Robust-CVD [21]	0.360	0.154	3.443	-	-	-	-	-	-
	ParticleSfM [48]	0.129	0.031	0.535	0.275	0.155	0.750	-	-	-
	CasualSAM [47]	0.141	0.035	0.615	0.209	0.202	0.620	-	-	-
	MonST3R [29]	0.108	0.042	0.732	(0.512)	(0.075)	(0.566)	-	-	-
w/ intrinsics	BA-Track (Ours)	**0.034**	**0.023**	**0.115**	**0.028**	**0.009**	0.150	**0.385**	**0.066**	1.029

Dynamic Reconstruction



More Studies



(a) Motion decoupling retains dynamic points in their original (static) positions

(b) Global refinement fixes scale drift → improves 3D consistency